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LIVING STARS*

By Anne B. Underhill

In this paper I wish to direct your attention to the fact that since stars are continuously emitting energy, part of which we receive as starlight, they must be slowly changing, evolving, or if you like, running down. I wish to put before you some of the more recent ideas on stellar evolution, and to discuss their consequences. All of us are familiar with the fact that living creatures change as they grow old. Their size and appearance changes, their ability to work changes. We need only to think of the differences between an infant, a youth, and an old man to recognize this. The title of this paper has been selected to emphasize that similar changes happen during the lifetime of stars. Their size changes, the quality of the light they emit changes, and the total energy they emit changes as time passes. Stars, of course, do not *live* in the way human beings and plants or animals live. Nevertheless, they do undergo non-reversible changes as time passes. In this sense they may be said "to live".

In recent years science fiction has gained an increasing grip on the public imagination. The subject of stellar evolution might seem better to be the subject of science fiction than of true scientific research. However, I assure you that it is a field where progress can be made, in fact only will be made, by the application of the scientific method.

To make any progress with our subject we must make extensive use of the scientific method. That is, we must use logical thought and knowledge of the laws of physics to develop a firm web from the few possible observable facts to the question we are asking, namely, how may the stars be expected to change in the course of several billion years?

In the next few paragraphs I shall outline to you present-day thoughts on the evolution of stars, particularly on the life histories of the hotter

*An address to the Victoria Centre.

stars. What I shall have to say cannot be rigorously proved in its entirety down to every last detail. Nevertheless, it is unlikely that stars evolve in a manner much different in detail from the way I shall outline to you. The underlying assumption in all our work is that the laws of physics remain the same everywhere in the universe and for all times.

The life history of a star may be summarized as follows:

1. A star is formed and begins to shine.
2. It produces light more or less steadily for a certain length of time.
3. It stops generating energy and gradually fades away.

The time scale for these events is of interest as well as the total amount of radiation emitted at any one time, its quantity and its short-period variations.

Let us consider in general terms what a star is. A star is a large ball of gas with a mass of about 10^{32} to 10^{34} grams. Now 10^3 grams equals approximately 2 pounds, therefore an average star will weigh about 2×10^{30} lb. or 10^{27} tons. Because of its great mass, this ball of gas is very hot inside and the pressure is very high. Under these conditions nuclear reactions may take place generating energy. Thus the star shines. Our largest planet, Jupiter, has a mass about one one-thousandth that of the sun. This mass is too small for Jupiter to become hot enough inside to generate its own light. Therefore, there is a lower limit to the mass of a possible star.

The observed range in stellar masses is from about 0.1 solar mass to less than 100 solar masses, that is, not more than a factor 1,000. On the other hand the range in intrinsic luminosity (bolometric absolute magnitude) is about 25 magnitudes or a factor of 10^{10} (10 billion). Thus the known range in luminosity is at least 10 million times that in mass. From this comparison we draw the conclusion that at least during part of their life some stars either draw their energy from processes that produce much more energy per unit mass than ordinary processes do, or else they are burning ordinary fuel (hydrogen) at an exceptionally fast rate. Faint stars such as the white dwarfs produce hardly any energy per unit mass in comparison to this.

Most of the stars are not very luminous. In fact, most stars are less bright intrinsically than the sun. A few stars are much brighter than the sun, some being exceedingly bright. These are the most interesting stars from the evolutionary point of view, for if they are generating energy by ordinary processes but at a faster rate than usual, their lifetime cannot be more than about 10 million years. After that time they will run out of fuel and need refueling. What sort of change can be expected to occur? Can it be detected?

A star is gaseous throughout, and its composition is about 83 per cent. hydrogen by weight and about 17 per cent. helium with a trace of all the other elements. The composition will remain the same throughout the lifetime of a star except in the very innermost regions where the energy is generated by nuclear reactions. Here hydrogen is slowly changed to helium by means of the well-known carbon cycle process or by the proton-proton reaction which is the type of reaction that occurs in a hydrogen bomb. At later stages in the star's development, it has been postulated that elements heavier than hydrogen are "burned", and that consequently some of the heavier atoms are formed instead of helium. However, unless there is a strong mixing process going on through the star, the changed composition of the interior will not affect the exterior layers which are all we can observe. There are good theoretical reasons to believe that practically all the stars we see are unmixed.

Let us now consider the life history of a star in more detail.

1(a). *Star is formed.* It is considered that stars are formed from clouds of interstellar dust and gas which under self-gravitational attraction begin to contract. It is known that interstellar gas is in turbulent motion, and just how a sufficiently large density irregularity could occur so that contraction could start in a turbulent medium is difficult to prove. Perhaps the weak interstellar magnetic fields turn the trick. I cannot outline to you an unobjectionable detailed physical process by which stars are initiated from the interstellar material. Nevertheless, the inference is clear from several lines of evidence that what we know as stars originated from the gas and dust clouds.

1(b). *Star begins to shine.* Stars begin to shine as a result of the energy released by the gravitational contraction of the large gas and dust cloud. The amount of energy released depends upon the mass of the object. Massive clouds, about 10 solar masses, will contract to stellar dimensions in a matter of 10^5 to 10^6 years; less massive clouds will take longer.

2. *Star produces light.* As the star contracts the central regions become dense and very hot, the central temperature eventually reaching some millions of degrees. Dense gas is quite opaque to radiation in most wavelengths, and the resulting opacity of the stellar material will tend to dam back the energy generated in the centre and make the temperature here even hotter. The star will adjust to equilibrium conditions so that at low central temperatures the proton-proton reaction occurs, while at high central temperatures (which occur with large masses) the hydrogen is transmuted to helium according to the series of nuclear reactions known as the carbon cycle. During this stage of development the star will change little in size and luminosity. The energy generation occurs within

a central convective core in a massive star, while in stars of mass less than the sun the central region is not convective. After a length of time depending upon the mass of the star, the content of hydrogen in the central region becomes so depleted that hydrogen burning cannot produce enough energy to sustain the star. The star must then adjust itself to another stage of life. For a star of about 10 solar masses, this first hydrogen burning stage may last about 5×10^7 years. For stars of solar mass the lifetime in this stage is close to 5×10^9 years, while for less massive stars the lifetime is even longer. The massive star, having exhausted its hydrogen in the central core, begins to contract again. Eventually the temperature in a fringe of material around the central core reaches a sufficiently high temperature for the hydrogen burning to start again, and the star settles down to another shorter period of quasi-equilibrium. If the temperature in the core becomes high enough, the star begins to burn helium and other elements. This process continues until nothing more can be burnt in the core.

3. *Star stops shining.* When a star can no longer generate energy by nuclear reactions it must cool down. The light escaping from the star will be the result of thermal cooling only. When stars are so cool that they emit no more visible light they may be called dead. White dwarfs are stars that are dying, for their luminosity can be accounted for solely by cooling. No energy is being created by nuclear reactions or by gravitational contraction. The stellar material is completely condensed and it is just cooling slowly. In order to become white dwarfs the early-type stars have to lose some of their mass, for the maximum possible mass for a white dwarf is of the order of one solar mass. A. J. Deutsch (1956) and J. L. Greenstein (1956) consider that some of the extra mass of the heavy stars is ejected into interstellar space during the red-giant stage of a star's development. Some O and B stars have shells of gas around them which show up as the "Be" or "shell" phenomenon. It is possible that these stars are slowly losing material to interstellar space, but it is difficult to think of them losing enough mass in this way to become white dwarfs. After all, the mass of an average Be star is probably 8 to 10 solar masses. The mass of an early B star or an O star is two or three times this. We reach an impasse here. White dwarfs are presumably very old stars which have exhausted the usual sources of energy. Should we think of them as having originated from stars with masses near the solar mass, our calculations indicate that it will take at least 5×10^9 years to go through the hydrogen-burning part of life, and somewhat longer to finish the following stages of development. On this basis it is not unlikely that their life has been as long as 6×10^9 years, which is a very long

time even on the time scale of the universe. If we think of the white dwarfs as having originated from early-type stars, then their minimum age may be less than 5×10^9 years, for massive stars proceed through the various stages of evolution faster than solar-type stars do. However, we now have the severe problem of explaining how the massive stars could lose as much as 9/10 or more of their mass and still remain stellar entities.

According to the schedule for evolution outlined above, stars with masses greater than about 5 solar masses must have changed considerably during the period of about 5×10^9 years in which our sun, according to geological evidence, has not changed much. The massive stars are chiefly the O and B stars. The O and B stars occur in groups in the spiral arms of our galaxy, usually in regions full of interstellar dust and gas. Is there any evidence that some of the O and B stars may be younger than others?

It has proved feasible to characterize the physical description (size, quality of light, effective temperature, etc.) of a star by its position in the Hertzsprung-Russell (HR) diagram. In this diagram the stars are plotted with visual absolute magnitude as ordinate and spectral type as abscissa. The equivalent theoretical quantities are the bolometric absolute magnitude as ordinate, and the effective temperature as abscissa. In figure 1 are shown the evolutionary tracks in the HR diagram of stars of different masses. This diagram is schematic and it has been constructed from the

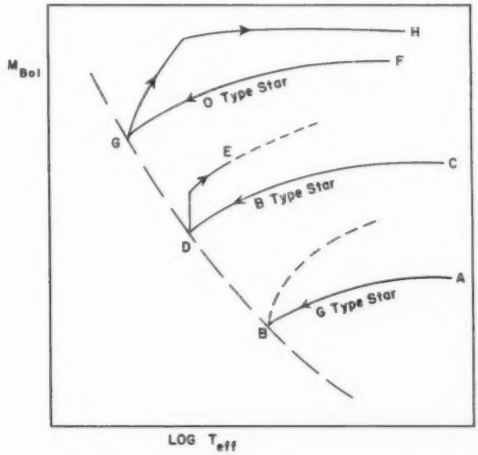

FIG. 1—Schematic evolutionary tracks of stars in the Hertzsprung-Russell diagram.

work of R. S. Kushwaha (1957) and R. J. Tayler (1954) on the evolution of stars. The observed main sequence is shown as a broken line. Most of the stars we observe fall on this line. The most massive stars reach the highest point on the main sequence; the less massive stars reach lower points. The stars start at the right-hand side of the diagram and in the course of time follow the tracks in the direction of the arrows. The speed at which a star moves along the track appropriate to its mass depends upon the mass of the star. The most massive stars evolve the fastest. Furthermore, the stars are believed to go at different rates through the various sections of the track. The available estimates of the time spent by any one star in any stage of development are not very consistent or sure yet. However, it is clear that stars of solar mass or thereabouts will hardly have had time to do more than contract to the main sequence (section *A-B* of lowest track), and remain on the main sequence, point *B*, in 5×10^9 years. Stars of about 5 solar masses (B5 stars) may have traversed the track *CDE* in 5×10^9 years, whereas an early B star with a mass of the order of 10 solar masses might well have evolved past the point *H* from point *F* in only 5×10^7 years.

Now let us suppose that a group of stars with masses equal to those of O and B stars as well as A, F, G, and K stars was formed 10^9 years ago. What would we expect the HR diagram to look like? By cutting the tracks of figure 1 at 10^9 years one would get an array somewhat as sketched in figure 2. This would be the type of HR diagram to be ex-

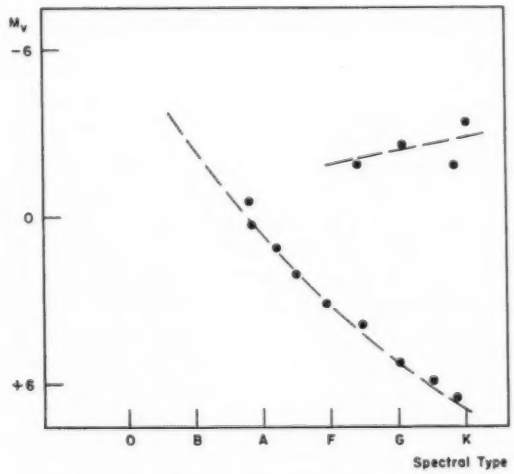

FIG. 2—Schematic HR diagram for an old cluster.

pected for an old galactic cluster. There are no O and B stars for they have evolved past this stage into the red-giant stage or even further.

After only 10^7 years the HR diagram might look as in figure 3. Here, a few of the O and B stars have moved off the main sequence a little bit, but some of the G and K stars have not even reached the main sequence.

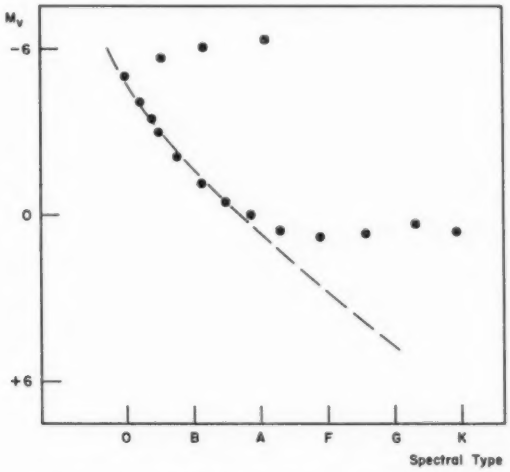

FIG. 3—Schematic HR diagram for a young cluster.

Some astronomers such as W. W. Morgan* and M. Walker (1956) suspect, on this basis, that the Orion cluster and NGC 2264 in Monoceros are very young. A cluster such as the Pleiades is older, and the Hyades cluster is much older. There are no O and B stars in the Hyades, but there are some white dwarfs.

Much theoretical and observational work must be done before these ideas can be confirmed or denied. In the meantime we should consider this idea of recognizing stellar groups of different ages a distinct possibility. It is exciting to think that some of the G and K stars in Monoceros may be right now only in the preliminary contracting stage of life. If this is true these stars have been formed since most of our galaxy was formed.

However, all is not entirely sure. J. A. Pearce* has pointed out one serious hurdle that the above theories of stellar evolution must overcome.

*Private communication.

About one-third of the O and early B stars that have been studied in detail are binaries. In fact O and B stars occur very frequently as pairs of like stars. According to the theories sketched above a star of sufficient mass to be what we call an O star when it is in a quasi-stable state on the main sequence must evolve quite quickly into a B- or A-type supergiant. A pair of O stars would, one presumes, evolve into a pair of supergiants. Unfortunately, no pairs of supergiants are known! We regretfully conclude that fascinating as the present theory is, we do not really yet know in all details how stars evolve. The theories sketched here are valid for single stars. Will the evolutionary pattern be changed if there are two stars close together? This we do not yet know. Upon our answer to this question hangs our faith in the life history we have deduced for a massive star.

The universe is probably much older than our sun and solar system which in turn are probably significantly older than many O and B type stars. This conclusion comes from efforts to account for the formation of the chemical elements. Two fairly well established points are relevant here. (1) The relative abundances of the elements are not the same in all observable parts of the universe. Some stars clearly contain a greater proportion of metal atoms and/or helium atoms to hydrogen than others do. (2) The more satisfactory theories of the formation of the chemical elements and the building up of heavy atoms from the fundamental particles of physics envisage that the necessary nuclear reactions take place inside starlike bodies. Put briefly, this scheme of things implies that there have been several generations of starlike bodies before our sun and its neighbours were formed. The age of the sun and solar system may be something like 5 billion years. W. A. Fowler (1956) from consideration of the relative abundance of the uranium isotopes and of the problem of synthesizing the elements, estimates that the time of element synthesis was at least 6 billion years ago. Are the white dwarfs remnants from this time? Recent work by F. Hoyle and C. B. Haselgrove (1956) suggests that the globular cluster M3 may be a little more than 6.5 billion years old.

In comparison to these ages, the lifetime of a massive object which we recognize now as an O or B star is very small, being perhaps 1/100 of the time that has elapsed since the chemical elements were formed in the relative abundances we now have or since the stars of M3 were formed. The time for our galaxy to rotate once is about 2×10^8 years. The lifetime of the O and B stars is probably smaller than this time also. Since the O and B stars delineate the spiral arms, this last conclusion implies that the spiral arms of our galaxy will not look the same for a period longer

than one revolution. It is obvious that the appearance of a galaxy must change as the stars evolve. It follows that galaxies which have prominent spiral arms comprising most of their bulk are "young", or at least "rejuvenated", whereas galaxies that have little or no dust and gas and are composed mostly of late-type stars are "old". The latter type of galaxy would be classified as an elliptical galaxy. We see, therefore, that our universe contains not only living stars, but living galaxies, for all are undergoing non-reversible changes.

This talk developed from conversations and discussions with W. W. Morgan, J. A. Pearce, and R. S. Kushwaha as well as others at the Dominion Astrophysical Observatory. I have drawn heavily upon the ideas of W. W. Morgan and R. S. Kushwaha in particular, and I would like to thank them for the assistance they have given me in preparing this material. References to recent papers on stellar structure and problems relating to stellar evolution will be found in the report of the symposium on Stellar Evolution held at a joint meeting of the American Astronomical Society and the Astronomical Society of the Pacific, August 27, 1956 (*Pub. Astron. Soc. Pac.*, vol. 68, p. 495).

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Dominion Astrophysical Observatory,
Victoria, B.C.,
March 1957.

RESOLUTIONS PASSED AT THE NATIONAL SCIENCE FOUNDATION CONFERENCE ON BINARY STARS HELD AT VICTORIA, AUGUST 16–18, 1956

At the Binary Star Conference held at Victoria last August a number of resolutions were passed dealing with the progress of double star astronomy and the need for certain developments to ensure that progress would be continued in this important field of astronomy. The papers presented at the Binary Star Conference were printed in the February issue of this Journal and we now give here the resolutions passed at this same Conference.

1. The Conference considers the incorporation of a large reflector in the equipment of the National American Observatory, as planned by the National Science Foundation, to be most important in furthering studies of double stars.

2. The Conference concurs in and supports the resolution of the National Science Foundation Conference on the Cosmic Distance Scale, held at the University of Virginia, as related to an engineering study for a large reflector for astrometric purposes. Such a telescope will make possible important studies of intrinsically faint binaries for which adequate telescopic power is not now available.

3. The Conference expresses its interest in the development of computations on orbital and photometric data for binary stars with the aid of high-speed digital computers at the University of Toronto. The Conference hopes that support can be obtained to continue and to develop further this work.

4. The Conference endorses the programme of the National Science Foundation for the establishment of large-scale computation facilities, in view of the increasing need for such facilities in double-star astronomy.

5. The Conference emphasizes the importance of a telescope of adequate size located in the southern hemisphere and suitable for photometric and astrometric studies of binary stars.

R. M. Petrie

A POSSIBLE METEORITE CRATER AT DEEP BAY, SASKATCHEWAN*

By M. J. S. Innes

Abstract

The waters of Deep Bay, which form the south-eastern part of Reindeer Lake in Northern Saskatchewan, occupy a circular depression having an average diameter of about 8½ miles. Its depth, from the highest point on the rim to the bed of the lake, is about 1,130 feet.

Topographical, geophysical and geological evidence strongly suggest that this circular feature has been formed by explosion. The impact of a large meteorite seems the most probable explanation, although no meteoric material so far has been discovered. Several other hypotheses are discussed and rejected.

Introduction

The increasing number of circular depressions on the earth's surface which, in recent years, have been proven to be explosion craters formed by impact of high-velocity meteorites, suggests that such features are not so rare as formerly believed. Moreover, it would seem that the great Precambrian Shield areas, characterized by vast exposures of granitic rocks, favours the preservation of fossil meteorite craters and provides one of the most fruitful regions for their discovery. Although positive identification in the form of meteoric material has yet to be established, it is perhaps significant that three craters all greater in size (and two of which are of much more advanced age) than the great meteor crater in Arizona, have been discovered in the Canadian Shield since 1950. These are the New Quebec Crater (Meen, 1950) located in the Ungava region of northern Quebec, and the Brent and Holleford craters (Beals, Ferguson and Landau, 1956), both in southern Ontario.

Another crater-like structure having a diameter at least four times as great as the largest of these, also lies in the Canadian Shield. Known as Deep Bay, it is situated about 250 miles north of Prince Albert, Saskatchewan (see figures 1 and 2), and forms part of the southern end of Reindeer Lake. It is inaccessible by ground transportation methods and can most easily be reached by aircraft. The centre of the feature has co-ordinates 103° 00′ west longitude, and 56° 24′ north latitude.

Although first observed by the writer in 1947 while making regional gravity measurements in northern Canada, it was only after recent investi-

*Contributions from the Dominion Observatory, vol. 3, no. 8. Published by permission of the Deputy Minister, Department of Mines and Technical Surveys, Ottawa, Ontario.

gations of other crater-like objects that attention was again focused on Deep Bay. During the month of August 1956 an expedition was organized by the Dominion Observatory in co-operation with scientists from the Mineral Resources Department of the Province of Saskatchewan, to examine the crater and attempt to determine its origin. The party consisted

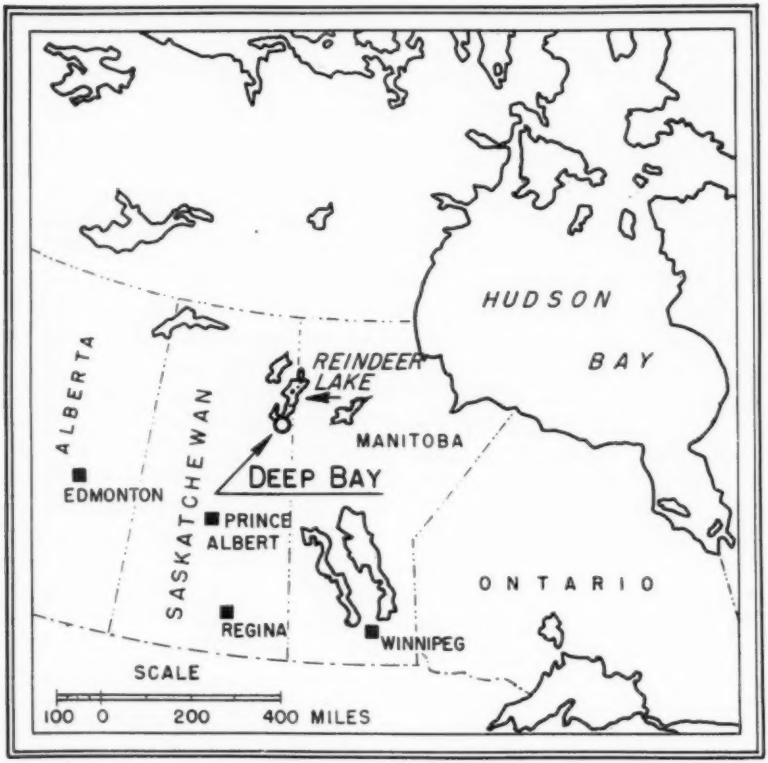

Fig. 1—Location Map of Deep Bay Crater.

of myself; J. W. Geuer of the Dominion Observatory, as assistant; W. A. Pearson of the Mineral Resources Department of Saskatchewan, as geologist; and W. Douglas of Reindeer Lake, as boatman and cook. Topographical, geophysical and geological studies were carried out and although the results have not been fully analyzed, preliminary examina-

tion suggests the feature originated from a tremendous explosion for which no cause other than the impact of a huge meteorite can be suggested.

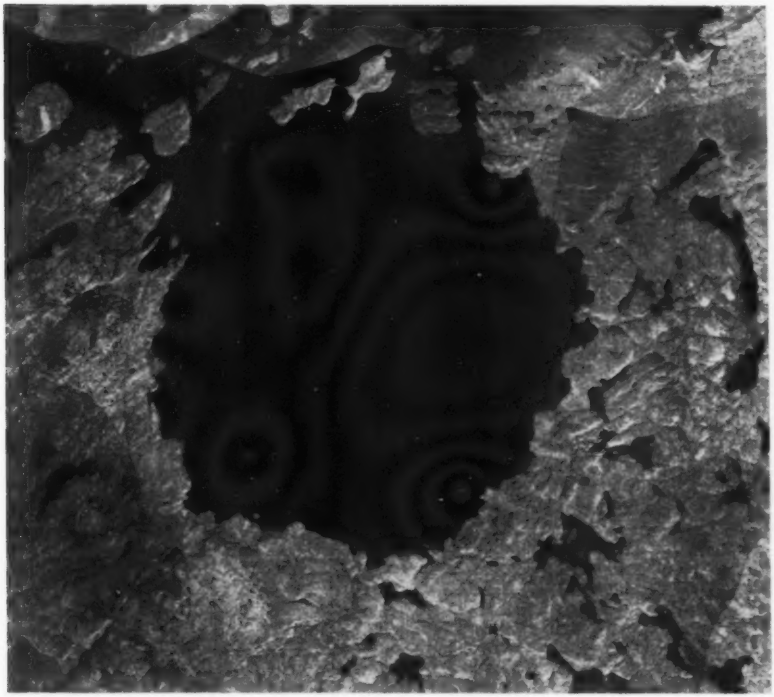

FIG. 2—Mosaic of Deep Bay prepared from aerial photographs taken by the Royal Canadian Air Force. Mean diameter of the Bay is 6¼ miles. North is upward as in the map of figure 1.

Description

There is much evidence that the formation of this feature took place prior to the last period of glaciation and as a result many original and distinguishing characteristics have long since been obliterated or profoundly altered. Fragmentary materials ejected by the explosion, that normally would be strewn radially from the point of impact or heaped about the periphery to form a rim have been removed. While some of these materials may have been pushed back into the depression by ice

movement, most will have been swept away to lose their identity within terminal moraines and other glacial deposits.

Nevertheless, much of the bedrock portion of the rim remains and is sufficiently prominent to isolate the feature more or less from the general drainage system of the area. The waters of Deep Bay which occupy the bottom of the crater and form nearly a complete circle with a diameter of about 6¼ miles are controlled by an outlet into Reindeer Lake on the north-west margin of the bay. All other drainage into the crater is confined to short intermittent streams of no greater length than two miles.

The rim has a mean diameter of about 8½ miles and stands on the average about 270 feet above the surface level of Reindeer Lake, which has an elevation of 1,106 feet above mean sea-level. It is best preserved to the north-east and east where it reaches an elevation of more than 1,520 feet. Here also, the inner slopes are steep and in many places precipitous. The advance of the ice apparently was from the north-east and erosion has been much more effective to the south-west and west. Here the rim stands lowest and has the appearance of broken, flat-topped hills with gently sloping surfaces.

Numerous soundings of the waters of Deep Bay show a maximum depth of 720 feet. The lowest portion of the crater floor, which is off centre and closest to the eastern edge, has, therefore, an elevation of 386 feet above sea level and lies approximately 1,130 feet below the highest portion of the rim.

Geological and Structural Evidence

There is no evidence from the geology of the region to suggest that the crater might be the result of differential erosion or due to the more rapid weathering of less resistant rocks. The rocks of Deep Bay are all Precambrian in age and typical of those in the surrounding country. They are chiefly schists and gneisses of sedimentary origin which are highly metamorphosed and granitized. Apart from a few thin beds of impure limestone which form a small part of the sedimentary gneisses to the north of the bay, no soluble rocks are known to exist. The strongest evidence against an erosion theory is provided from numerous observations of the strike and dip of foliation and bedding of the gneisses. These show that in a broad way, the general structural trend is north-easterly, while locally, many structures are abruptly terminated at the crater's margin.

The possibility that Deep Bay occupies the site of a former volcanic crater is also extremely doubtful. With the exception of a belt of ancient volcanic rocks several miles to the north-west, there is no sign of volcanism or volcanic rocks in the area.

Good rock exposures around the inner wall of the crater are plentiful and all that were examined show signs of major shattering and fragmentation. The jointing, which has resulted in the formation of huge angular blocks, decreases in intensity with increasing distance from the rim. However, numerous fractures or fault zones of varying widths which cut across the rim at various angles, both radial and oblique, persist for several miles. The country is heavily wooded, chiefly with small spruce, pine, birch and poplar. The fracture pattern modified by glacial action and deposition, which is difficult to trace from ground observation, can readily be followed from an aircraft or aerial photographs by observing where the birch and poplar trees are most abundant.

Until the results of ground investigation are available, no attempt can be made to separate the features which are to be attributed to the regional structure, from those that might be related to the formation of the crater. However, it may be said that the highly fractured terrain has the overall appearance one might expect if the granite masses for several miles surrounding the basin has been uplifted to considerable heights and shattered on collapse.

Gravity Evidence

The geophysical results provide further evidence of an explosive origin. Numerous gravity measurements were made around the crater and along certain traverses radiating from it for several miles. Corrected for irregularities of terrain, the results show an increase in gravity in all directions from the margin of the Bay. This is believed to reflect disturbed bedrock conditions and fracturing to great depths beneath and in the vicinity of the rim. Similar gravity fields have been noticed in association with other circular features (Innes, Willmore and Clarke, 1954) and it may be found generally that such surveys provide important diagnostic evidence of explosion features.

Discussion

The great size of Deep Bay sets it sharply apart from other similar topographic features. The famous Meteor Crater of Arizona is the largest whose meteoric origin has been established (Barringer, 1909) beyond all reasonable doubt. Proof of a similar origin for the Deep Bay depression which is eleven times greater in diameter, would be, therefore, of great scientific interest and importance. At present there is only one criterion by which the meteoric origin of a crater may unambiguously be established. This is the occurrence of meteoric material in association with the crater itself. Although only a cursory examination of the area surrounding Deep Bay has been made, no such fragments or associated

materials have so far been discovered. Because of the great age of the crater and the consequent glaciation effects, the chances of such evidence being discovered are, unfortunately, extremely small.

However, what may prove to be of prime importance in establishing a meteoric origin was the discovery of boulders and pieces of shale on a small beach near the southern end of the Bay. Although quite hard (about 4 on Mohs scale) and compact, the shale is poorly cemented and breaks readily into plates, when struck with a hammer. It has not been found *in situ*, but is believed to have been carried by ice movement from a lake deposit on the floor of the crater. The shale may have originated, in part, from finely powdered rock material, resulting from the explosion. It is being carefully examined to determine if it is petrographically similar to the rocks surrounding the crater, for evidence of high temperature and fusion, and for any particles or splinters of the meteorite that may have survived the processes of weathering.

The preceding has been a preliminary account of an investigation which is only in the initial stages. The complete results will be reported elsewhere.

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COMMUNICATIONS
FROM THE
DAVID DUNLAP OBSERVATORY
UNIVERSITY OF TORONTO
Number 41

PHOTOMETRIC OBSERVATIONS OF 12 LACERTAE

By G. A. Bakos

The star DD or 12 Lacertae belongs to a group of variables known as β Cephei or β Canis Majoris stars. They all are of early spectral types, B1–B2, and exhibit short-period variations both in brightness and in radial velocity.

The first discovery of variability of this kind was made in 1902 by Frost of the Yerkes Observatory. One night he took two spectrograms separated by five and one-half hours of the bright star β Cephei, and after reduction he found a change in velocity of 14 km./sec. Four years later he announced the period to be 4½ hours and the velocity range 34 km./sec. At that time it was thought that all velocity changes were caused by orbital motions of binary systems. In the case of β Cep this would have meant that two stars were in contact or one moving inside the other.

A systematic search for similar objects yielded about a dozen of these "β CMa stars". In addition to velocity changes, variability in light was also detected.

Today, we know that this group of stars is of the same type as δ Cep or RR Lyr variables. The cause of changes in brightness and velocity lies in a pulsation of surface layers. About one-half of the known β CMa stars exhibit a double pulsation with two slightly different periods. Therefore, the light or velocity curve does not repeat itself after one period but only after a cycle known as a beat period. Now, in the case of 12 Lac the two periods are 4^h44^m and 4^h38^m. The resulting beat period is about 9 days.

Among β CMa stars there is a strong relation between the primary period and the spectral type. To an earlier spectral type corresponds a longer period. The luminosities of these variables are slightly above those of the main sequence stars for spectral types B1 and they gradually merge into the main sequence for spectral types B2 and later. As for

the individual spectral lines, it was noted that their intensities are not always constant and the lines sometimes become double. This occurs at a certain phase only and leads to a discontinuous velocity curve. It is probable that these phenomena are connected with pulsations of different photospheric levels.

Dr. C. de Jager of the Observatory of Utrecht realized that the many problems concerning β CMa stars which still remain to be solved might best be attacked by an organized international drive on one of the stars. He proposed that a number of observatories around the globe should make concentrated observations of the star 12 Lac by both spectrographic and photometric means during the period from August 28 to September 12 and again from September 27 to October 12, 1956. Such a combined effort was made with the spectrograph and photometer at the David Dunlap Observatory. While the measurements of 195 spectrograms have not yet been completed, the writer of this note will discuss briefly the results of his photoelectric observations, made with the 19-inch telescope.

The star 12 Lac was observed here for the first time on the night of September 2/3 from 22^h42^m to 3^h42^m E.S.T. and again on the night of October 10/11 from 19^h35^m to 1^h05^m E.S.T. in two colours, in blue and yellow. For a comparison star 10 Lac was chosen; it happens to be one of Johnson's primary standards and it is at a distance of just a little over 1° from the variable. Because both stars are of nearly the same spectral type and because of the short distance between the stars no correction for differential extinction was necessary. In reducing the observations the magnitudes of the comparison star—on an arbitrary scale—were represented graphically and interpolated for the time of observation of the variable. Then the difference was formed for both colours which is represented in the following table. The first column lists the Julian Date of observation corrected for the light equation of the orbital motion of the earth. The second and third columns contain the magnitude difference, 10 Lac minus 12 Lac, for blue and yellow colours respectively; the last column is the colour variation of 12 Lac. The light curves of the visual region (Δm_y) of both cycles are represented in the figure. A similar curve in the blue region can be readily drawn from data given in the table. It will be noticed that the amplitude of the light variation is quite different for the two intervals represented. This relates to the double period referred to earlier.

The present observations are not sufficiently extensive to warrant a detailed discussion of the nature and periodicity of the light variations. However, it is hoped that they will be useful for this purpose when they are combined with other series of observations made elsewhere.

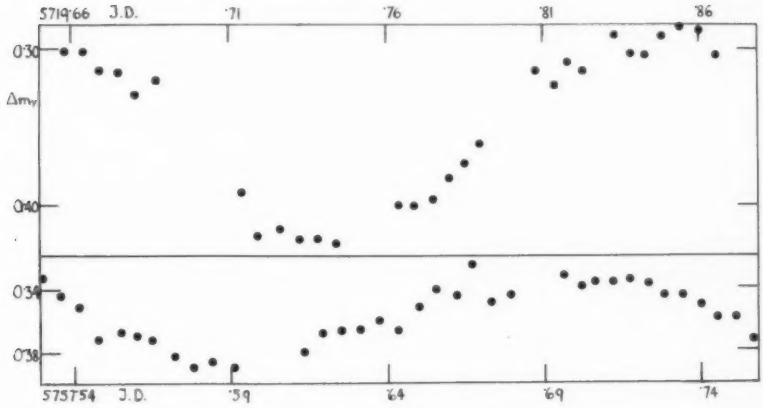

FIG. 1—Photoelectric observations of 12 Lacertae.

OBSERVATIONS OF 12 LACERTAE

J.D.	Δm_B	Δm_y	C	J.D.	Δm_B	Δm_y	C
2435719.658	+0.373	+0.302	+0.071	2435757.548	+0.427	+0.371	+0.056
.664	0.364	0.302	0.062	.555	0.434	0.368	0.066
.669	0.379	0.314	0.065	.560	0.432	0.370	0.062
.675	0.384	0.315	0.069	.565	0.432	0.372	0.060
.680	0.388	0.330	0.058	.572	0.454	0.383	0.071
.687	0.399	0.320	0.079	.578	0.462	0.390	0.072
.712	0.474	0.392	0.082	.584	0.457	0.386	0.071
.719	0.485	0.419	0.066	.591	0.458	0.390	0.068
.726	0.490	0.415	0.075	.613	0.443	0.380	0.063
.732	0.492	0.421	0.071	.619	0.440	0.368	0.072
.738	0.492	0.421	0.071	.625	0.431	0.366	0.065
.744	0.496	0.424	0.072	.631	0.425	0.366	0.059
.764	9.467	0.399	0.068	.637	0.433	0.360	0.073
.769	0.470	0.400	0.070	.643	0.427	0.366	0.061
.775	0.465	0.396	0.069	.650	0.423	0.352	0.071
.780	0.457	0.382	0.075	.655	0.410	0.340	0.070
.785	0.437	0.373	0.064	.662	0.416	0.344	0.072
.790	9.422	0.360	0.062	.667	0.405	0.325	0.080
.808	0.390	0.314	0.076	.673	0.413	0.348	0.065
.814	0.388	0.323	0.065	.679	0.404	0.344	0.060
.818	0.374	0.309	0.065	.696	0.392	0.332	0.060
.823	0.375	0.314	0.061	.702	0.395	0.338	0.057
.833	0.325	0.291	0.061	.706	0.388	0.335	0.053
.838	0.357	0.303	0.054	.712	0.400	0.335	0.065
.843	0.362	0.303	0.072	.717	0.393	0.334	0.059
.848	0.353	0.292	0.061	.723	0.402	0.337	0.065
.854	0.341	0.286	0.055	.728	0.397	0.344	0.053
.860	0.348	0.289	0.059	.734	0.397	0.344	0.053
2435719.866	0.362	0.304	0.068	.740	0.407	0.350	0.057
2435757.530	0.403	0.333	0.070	.745	0.437	0.358	0.079
.536	0.408	0.344	0.064	.751	0.424	0.358	0.066
.542	0.414	0.351	0.063	2435757.756	0.433	0.372	0.061

THE 97TH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY

By J. B. Oke

This meeting, one of the largest meetings of the Society on record, was held in Cambridge, Mass., at the invitation of the Harvard College Observatory and the Smithsonian Astrophysical Observatory. In addition to the presentation of nearly 60 short papers, there was an afternoon conference on "The Scale of the Galaxy", a panel discussion about space travel, a special session concerning Comet Arend-Roland, a Society dinner, and a visit to the Agassiz station of Harvard College Observatory.

Of timely interest was a short session devoted to reports of observations of Comet Arend-Roland. Many beautiful and spectacular photographs of this comet were shown, showing the course of its development over a three-week interval. The comet's tail was observed to be about 40° in length; the unique jet pointing nearly towards the sun was 12° long. No satisfactory explanation for the jet was made. Several attempts were made to detect the comet with radio telescopes; but only Kraus, working at a frequency of 27.6 mc., was successful.

Perhaps the most important part of the meeting was the conference on "The Scale of the Galaxy". Dr. H. F. Weaver, the moderator, gave a summary of the various determinations of the distance to the centre of the galaxy. The value quoted most frequently, 8.2 kpc., is based on the average of Baade's distance using RR Lyrae variables at the centre of the galaxy and the distance derived by van de Hulst, Muller and Oort from the 21-cm. hydrogen radiation results. The latter result depends on the value of the constant of galactic rotation, *A*. Weaver demonstrated that the uncertainty in *A* is almost entirely due to the uncertainty in the distances of stars used in the determination. The purpose of the conference was to discuss critically the methods used for determining the distance to the centre of the galaxy.

Whitford discussed Baade's results and showed that on the basis of present knowledge concerning the interstellar reddening and the intrinsic colours of globular clusters, Baade had assumed too much interstellar absorption. Using the best figure for the interstellar absorption puts the centre of our galaxy considerably farther away. Dr. Cecilia Payne-Gaposchkin also discussed Baade's work from the point of view of the absolute magnitudes used for the RR Lyrae variables. She pointed out that there was evidence that RR Lyrae variables were not all of the same absolute magnitude, and that those at the centre of the galaxy used

by Baade were really fainter than average. The conclusions of their two papers suggest that the centre of the galaxy is somewhat more than 8.2 kpc. from the sun.

Schmidt discussed the 21-cm. hydrogen radiation and indicated that the results so far obtained could not be significantly in error. Taking the present results along with various values of A, he showed that the distance to the centre of the galaxy was greater than 8 kpc., perhaps as much as 12 kpc.

Stibbs discussed the problem of the scale of the galaxy insofar as it involved Cepheid variables. One of the most serious difficulties in using the Cepheid variables as distance indicators arises in correcting for interstellar absorption. To do this, intrinsic colours of these stars must be obtained. Using the best data possible, he has made a determination of A which differs little from the usually adopted value.

The final paper of the conference by Dr. van de Kamp dealt with the basic methods of determining stellar distance, by the parallax method and by proper motions.

The conclusions reached were that the distance of the centre of the galaxy was probably somewhat greater than 8 kpc., but it was stressed that uncertainty in this distance was still great.

For the first time, a large astronomical organization sponsored a discussion on space travel. The speakers included F. L. Whipple, C. M. Clemence and G. de Vaucouleurs. It was pointed out that space travel now is within sight of man. While the technical difficulties are enormous, no new basic knowledge is needed; money is the chief requirement. Clemence discussed the very relevant problem of space navigation and emphasized the importance of unmanned rockets. De Vaucouleurs speculated on what man could learn about Mars by approaching within a few hundred miles of its surface; clouds in the Martian atmosphere would be a major consideration.

The sixty short papers touched on almost every branch of astronomy. Papers concerned with astrophysics emphasized over and over again the importance of stellar evolution. Papers were given on such subjects as the origin of the heavy elements, cosmic rays, stellar systems, the artificial satellite, meteors and meteor craters.

The meeting concluded with a visit to the Agassiz station where the various telescopes including the new 60-foot radio telescope were on display.

COMET AREND-ROLAND

This Journal has received many informal communications from both amateur and professional astronomers in Canada concerning observations that were made during the recent appearance of Comet Arend-Roland. The following is a brief summary of some of these—Editors.

Comet Arend-Roland was the most spectacular comet seen in the northern sky for many years. It was first discovered by S. Arend and M. Roland of Belgium on photographs taken on November 8, 1956, but was not announced until November 19. As is the practice, the comet was named after the discoverers, and also has the designation 1956h (the eighth comet found in 1956).

When first found, it was diffuse and of 10th magnitude, near Triangulum, and was moving south-westward. It continued through Pisces during December and January, getting closer to the sun and brightening. It was lost in the glare of the sun until the last half of April. By this time it was back-tracking and moving northward. It became a circumpolar object in Ursa Major by the end of May.

The orbit of the comet was computed independently by several astronomers who got accordant values. The comet went north in the evening sky as a result of the orientation of its orbit and particularly high (60°) inclination to the plane of the ecliptic. It was at perihelion passage on April 8, 1957, when its distance from the sun was only 29.7 million miles. It was closest to the earth about April 20 (53 million miles). By the end of May it was 154 million miles from the earth, and 123 million miles from the sun, and was no longer a naked-eye object.

Comet Arend-Roland was intensively observed by both amateur and professional astronomers. Montreal and Edmonton Centre observers picked up the comet on Easter Sunday, April 21, but Toronto observers were hampered by bad weather and did not have good views of the comet until the following week. Regular observations of the position, magnitude and details of the appearance of the comet have been made by the Montreal group. The Toronto Centre members concentrated on directing observing parties in different neighbourhoods of the city and on the lawn of the David Dunlap Observatory.

Since its reappearance in April, Comet Arend-Roland has been observed with all the telescopes at the David Dunlap Observatory. Because of unfavourable weather the first good photograph was not obtained until the night of April 28, with the 19-inch reflector, and also with the Zeiss camera attached to the 6-inch refractor. On subsequent nights the

comet was photographed at nearly every opportunity. By the end of May eleven plates had been taken with the 19-inch telescope and nine plates with the Zeiss camera. The tail extension is well shown on the Zeiss plates. The jet, reported pointing towards the sun, and visible for only a few days, can be detected on several of the plates. The series of photographs will be used in the Department of Astronomy for student exercises in measuring positions and computing orbital elements of the

FIG. 1—Comet Arend-Roland as photographed by Gustav Bakos at the David Dunlap Observatory on the night of April 13 with a Zeiss wide-angle refracting telescope

comet. The comet was observed on April 29 with the spectrophotometer of the 74-inch reflecting telescope of the David Dunlap Observatory. The tracing shows a number of band systems, but details are lacking because of the essentially slitless character of the instrument as it was used for the comet.

Dr. William Wehlau at the Hume Cronyn Observatory of the University of Western Ontario made a long series of observations of the brightness of the comet with a photoelectric photometer attached to the 10-inch refractor.

Dr. R. M. Petrie of the Dominion Astrophysical Observatory reports

that they obtained a number of fairly good spectrograms of the comet and several direct photographs (see figure 2).

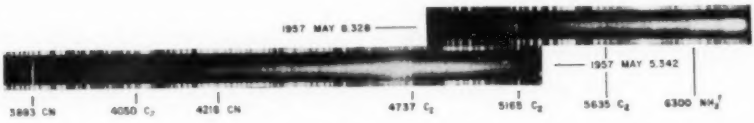

FIG. 2—Spectrograms of Comet Arend-Roland photographed at the Dominion Astrophysical Observatory.

At the Dominion Observatory the comet was observed quite a number of times with the 15-inch refractor and with binoculars, but was not on their research programme. Dr. C. S. Beals, Dominion Astronomer, reports that he was impressed with the sharpness and star-like quality of the comet nucleus. Also, he was fortunate in having a look at the jet-like extension of the comet during the few days it was visible. This phenomenon, which appears to be unique, probably will be the subject of discussion among astronomers for some years to come (see this JOURNAL, p. 244).

CANADIAN SCIENTISTS REPORT

VI. AIR NAVIGATION SINCE WORLD WAR II

By John F. Heard

Introduction

During World War II there was considerable interest in air navigation among astronomers, both professional and amateur. In fact, a good deal of reliance was placed upon those with astronomical training for the development and operation of training systems for air navigators. This was a natural outgrowth of the traditional position of navigation as a branch of applied astronomy. Since the end of the war, I believe few astronomers have had the opportunities to keep abreast of the developments in air navigation. These developments have been rather astonishing, both from the point of view of principle and technique, and a review of them should be of interest to astronomers.

At the outbreak of the war, air navigation was little more than marine navigation, adapted to take account of the greater speed of aircraft and the greater emphasis which has to be placed upon the effect of wind. Basically, the principles and even the technique, were the same as for marine navigation: the progress, or the proposed progress, of the aircraft was chartered by dead reckoning (D.R.) on a Mercator Chart, assuming that the aircraft's direction and speed in the air were measurable quantities, and assuming that the wind's direction and speed were known approximately; then, as the flight progressed, various navigation aids were called upon to fix positions, and from these "fixes" better values of the wind were derived and corrections were made to the heading of the aircraft.

Let us list, one by one, with remarks on their limitations, the elements of pre-war air navigation which have been implied in the foregoing paragraph.

(a) *The chart.* The Mercator chart, inherited from marine navigators, was poorly suited from the outset to the needs of air navigation except at very low latitudes. At the pole it was unusable.

(b) *The measurement and maintenance of heading.* The magnetic compass, the standard direction indicator at sea, has always been subject

to severe tests in an aircraft and in the regions of the magnetic pole it becomes useless.

(c) *Indication of air speed.* Air speed indicators operating from a pressure head outside the aircraft have managed, with various technical improvements, to continue to give satisfactory results.

(d) *Wind-speed and direction.* The early attitude towards the wind was one of resignation on the part of the air navigator. The wind was an act of God which sometimes helped, sometimes hindered the progress of the aircraft and which simply had to be coped with.

(e) *The chart work.* Even before the end of the war the speed of aircraft had increased and the tactical manoeuvres had become complicated to the point where the human navigator could no longer be expected to keep pace on a chart. The problem obviously called for a computing device which would accept the input of airspeed and heading of the aircraft and the speed and direction of the wind and would output the position of the aircraft.

(f) *Aids.* Aside from recourse to recognition of ground features, the pre-war and early-war navigator had the bubble sextant and several types of radio direction-finding systems. Fixing position by sextant ("astro") was limited to night operation, to clear sky, and it required more skill and confidence than many navigators possessed. Yet, it was self-contained, whereas the wireless fixing systems were, in wartime, subject to enemy "jamming" and sometimes subject to large errors through natural causes.

Let us now discuss how new principles and modern techniques have been coping with the limitations in these elements to adapt to high-speed flight.

Charts

The marine navigator became wedded to the Mercator chart because straight lines on this chart were the *rhumb lines* which he sailed when he followed a fixed course measured relative to true north. That the Mercator completely deteriorated at the pole didn't bother him because he never sailed in polar regions. That the rhumb line wasn't the shortest sailing over a long voyage at high latitudes was no great worry either; he divided a great circle route into a series of rhumb-line sailings and he found plenty of time en route to change from one rhumb-line sailing to the next. The air navigator should have seen from the beginning that the Mercator was not suited for his purposes (at least not in general), but the realization came slowly.

A Canadian, Group Captain Kenneth Maclure, was one of the pioneers

in the break from the Mercator. It had been realized that polar navigation required not only the abandonment of the Mercator chart, but the abandonment also of true north as the reference direction. In planning for experimental flights over the north pole during the war, Maclure proposed the use of a grid of parallel straight lines superimposed on a zenithal chart such as the Polar Stereographic. This grid was to be parallel to the Greenwich meridian and therefore came to be known as the *Greenwich Grid*. A route laid out on the polar chart as a straight line was essentially a great circle and, even if it passed close to the pole, it maintained the same direction relative to the grid—in contrast to its rapidly changing direction with reference to true north. The Greenwich Grid was therefore introduced for polar navigation, and it was not long before it was realized that a similar system had advantages in middle latitudes also. Thus the Lambert Conformal chart (on which the meridians are straight lines converging to the pole) was overlaid with a grid and used in much the same way as the polar charts. For low latitudes, however, the Mercator chart remains the best and the Greenwich Grid ceases to have any merit. (Indeed, at the equator the Lambert becomes the Mercator and the Greenwich Grid becomes the meridians.)

Thus nowadays, for the most part, airlines and air forces use the Stereographic in polar regions, the Lambert in middle latitudes and the Mercator near the equator. With the first two the grid reference system, for purposes of laying out and following courses, replaces the traditional reference system of true north. On this global system of charts, flight lines are virtually great circles, and rhumb-line flight has become a thing of the past.

The Maintenance of Heading

The magnetic compass remains the principal means of holding the aircraft on the required heading. However, in its post-war form, the compass is a far cry from the old liquid-filled bowl which used to be mounted in front of the pilot. The magnetic component, now gyro-stabilized, is mounted in a wing-tip or other spot remote from disturbing influences; its reading is transferred electronically to various positions in the aircraft. Basically, it refers the aircraft's heading to magnetic north, of course, but the navigator may, by setting a dial, make all the indicators read with reference to true north or grid north. Indeed, computing devices have been designed which will continuously transform the compass reading to grid direction.

When polar navigation began to be practised, one of the serious problems was the measurement of direction near the magnetic pole where

the horizontal component of the earth's field becomes nearly zero. Canadian navigators met this difficulty more often than others because of the location of the north magnetic pole in our territory. One of them, Wing Commander Keith Greenaway, was largely responsible for the technique which is now commonly used by practising navigators in the Arctic. This involves regular checks of headings by the stars with the Astro Compass or periscopic sextant, combined with short-term reliance on a direction-holding gyro as a sort of "memory" device between astronomical checks of heading. As better gyros of this type are developed there will be a tendency for them to replace the magnetic compass altogether. Such a system will tie in beautifully with the grid system of navigation, for the directional gyro, by the nature of things, holds a constant grid direction rather than "true" direction.

Wind

Toward the end of World War II, Royal Air Force navigators began to emphasize that, by skilful flight planning, routes and flight altitudes could be chosen so as to take advantage of more favourable winds. It became obvious that often a deliberate departure from the great circle route could result in a worthwhile saving of time and fuel despite increased distance covered. Out of this idea there was developed a system known as *pressure pattern* navigation. In this system the minimum-time route was chosen in the light of the meteorological forecast and then altered in flight in the light of atmospheric pressure conditions actually encountered. At about this same time, navigators and meteorologists began to be aware of the existence of the *jet streams*, localized regions of very strong winds usually encountered only at high altitudes. Efforts have been made on the part of meteorologists to forecast the jet streams and on the part of navigators to locate favourable jet streams and take advantage of them. Nowadays, some trans-ocean air lines, notably Trans-Canada, use a very carefully worked out system of minimum-time and minimum-fuel routing. It should be emphasized that the increasing ceilings and increasing range of modern aircraft are making these considerations more important for fuel economy, though the increasing speeds are making them less important for time saving.

Chart vs. Computer

The problems involved in navigating military aircraft are obviously very different from those of commercial aircraft. By the very nature of their duties and the hazards to which they are subject, pilots of military aircraft must engage in complex tactical monoeuvres. In modern high-speed flight it is manifestly impossible for a navigator—much less the pilot himself—to keep track of the many changes in heading and speed—

in other words, detailed chart work is out of the question. Since the war much attention has therefore been given to computing devices designed to accept an input of heading and airspeed from compass and airspeed indicator and to output present position at all times. Clearly the problem is complicated by the effect of wind, but a partial solution to this can be imagined in the form of a device which might add in the effect of the wind as long as its speed and direction are known. Such a computing device would relieve the navigator of the D.R. chartwork, but it would still leave him responsible for putting in the correct value of the wind. In this sense it is not a self-contained system.

One of the most successful computing devices of this kind is the R Theta computer invented by Wing Commander J. G. Wright of the Royal Canadian Air Force and developed and manufactured by P.S.C. Applied Research Limited, Toronto. The name of the device describes the way in which the position of the aircraft is presented, namely, on a dial as distance and position angle (named r and θ in polar coordinates) from the home airport or target.

The R Theta was designed for fighter aircraft and is being installed as standard equipment in the R.C.A.F. CF-100 jet fighter. I have outlined merely its basic function; its capabilities extend much further and include interception. Further, it is designed so that it may be slaved by such aids as *doppler* (see below) and thus it may be converted to a self-contained navigation system. Other devices of similar nature have been developed by Computing Devices of Canada, Ottawa.

Navigation Aids and Navigation Systems

By a navigation aid we mean a method of fixing position other than by dead reckoning; for example, wireless observations of direction or distance from ground stations or sextant observations of heavenly bodies (astro). If an aid appears to offer almost a complete solution to navigation problems it is customary to refer to it as a navigation system.

Under wireless aids we may include the systems used in the domestic flights of commercial airlines, for example, radio range and its more modern successors. Also, we may include in this class radar in its various forms including such systems as Loran on which Transatlantic carriers mostly rely. However, the military-minded navigator is inclined to dismiss these as "jammable" in wartime—although the British predecessor of Loran, a device called "Gee", was a big factor in the success of the R.A.F. bombing raids during the war.

One of the newest and most promising of radar aids is what is known as *doppler*. Readers will recall that, according to the Doppler principle, waves emitted by or reflected from a body which has a velocity of ap-

proach or recession relative to the observer will reach him with an altered wave-length or frequency, the change in frequency depending upon the relative velocity. Indeed, it is this principle applied to light waves which enables astronomers to measure the radial velocities of stars. Let us now imagine a transmitter of radio waves mounted on an aircraft and sending beams slanted down both forward and to the side, and also a receiver capable of measuring the changes in frequency of the waves reflected back from the ground. We can see that these frequency changes would measure the forward component of velocity relative to the ground and also the sidewise component. These are exactly the quantities which the navigator wishes to know—effectively they are the *ground-speed* and *drift* of D.R. navigation. By *doppler* they are now to be measured directly rather than, as before, compounded by the navigator from heading, air-speed and estimated wind velocity. Such a *doppler* device could be used in two ways: it could provide intermittent wind information to a D.R. computer such as the R Theta, which could then calculate the true wind, or, operated continuously, it could be the basis of an integrating computer which could indicate continuously the position of the aircraft. For military operations where there is some danger of the radiations being useful to the enemy, the intermittent use offers some advantage.

As one can imagine, the achievement of a dependable and accurate *doppler* system has not been easy, but several versions have been developed which operate successfully. Earlier this year Defence Research Board of Canada announced the development of one such, known as Drift and Ground-speed Measuring Airborne Radar ("Dagmar") which is being manufactured by Canadian Marconi Company.

Astro as an aid has had a chequered career of ups and downs in air navigation. At the end of the war it seemed completely obsolete, a victim of Gee and Loran and radar. Since the war there has been a revival of interest in astro, sparked partly by the greater ease and accuracy offered by the new periscopic sextants and new rapid methods of working out the sights and partly by the higher ceilings of aircraft which enable them to fly most of the time above the overcast. More recently there have been promising developments in "automatic astro", a long-dreamed of system in which a sextant, "locked" onto a pair of stars, could follow them and transmit the readings of altitude to a computer which would output continuous position of the aircraft. Such a system is feasible and may, in time, be a practicable reality—if it is not already.

Automatic or hand-operated, astro retains one enormous advantage: it is self-contained and absolutely "unjammable".

If one wished to be critical one could find fault in principle with any one of the aids so far referred to. Thus, astro is limited to clear skies,

and almost any wireless system could conceivably be jammed or else, to some degree, it violates radio silence. However, there is one system on which development is being carried out which would be entirely self-contained and independent. This is *inertial navigation*. The following explanation of the principle of this system involves rather absurd over-simplification, but it will possibly suffice for our purpose.

Suppose we could carry with us in an aircraft some indication of the *true* vertical or, what amounts to the same thing, a truly horizontal platform—achieved gyroscopically, let us say. Suppose further, that we have the equivalent of a pendulum bob or plumb line free to register the direction of the *apparent* vertical. Now if the aircraft is at rest the plumb line coincides with the true vertical, when the aircraft accelerates, the plumb line is deflected and the amount and direction of this deflection register the amount and direction of the acceleration, and when the aircraft acquires a uniform velocity the plumb line again coincides with the true vertical. We now imagine a computer which would integrate the accelerations into velocities and then integrate the velocities into distances covered, and thus finally record the position of the aircraft relative to the starting point. This is the principle of inertial navigation; the problems of achieving it in an accurate, reliable and practicable form are of the greatest difficulty. If it could ever be so realized there is little doubt that it would represent the ideal system of navigation.

Conclusions

To one who has been observing navigational developments from the sidelines during the past twelve years, it appears that we might think of them as falling into two categories. The first would comprise the new ideas and techniques which are really just improvements of war-time methods and which do not involve very elaborate, heavy or costly installations, and which are suited to the needs of commercial aviation of the present and of the immediate future. In this category I would put the new charts and methods of using them, the techniques of pressure pattern navigation, improved compasses and directional gyros, improved sextants and methods of working astro sights and improved wireless aids. In the other category I would put the more elaborate, more weighty and more costly systems such as D.R. computing devices, automatic astro, *doppler* and inertial navigation. These latter are very necessary for manned military aircraft of the present day; their role in the military aviation of the future can easily be left to the imagination.

David Dunlap Observatory,
Richmond Hill, Ontario.

NOTES FROM OBSERVATORIES

David Dunlap Observatory

A new accessory was added to the 74-inch telescope this spring, a photoelectric spectrophotometer. This device, designed by Dr. Oke and Dr. MacRae and constructed in the Observatory workshops by Mr. Longworth, is essentially a grating spectrograph which responds photoelectrically rather than photographically. The spectrum produced by the grating, which has a dispersion of about 30 A./mm., is swept slowly past an analysing slit which passes the light to a photomultiplier tube connected through an amplifying circuit to a pen recorder. Thus, in a few minutes there can be obtained an intensity record of the whole stellar spectrum which is similar to a microphotometer tracing but which is free of the errors introduced by the photographic method. The instrument operates very successfully and is being used regularly on a programme involving intensity distribution and line intensities in the spectra of a group of early-type stars.

Dr. MacRae's radio astronomy project has reached the stage of installation of equipment. A large horn antenna mounted in the meridian and an array of zig-zag elements mounted equatorially have been set up, and the receivers are ready. Signals from the sun have been recorded in test runs, and a programme is planned for monitoring the sun on 300 megacycles during the International Geophysical Year.

Comet Arend-Roland was photographed on a number of nights in April and May by Mr. Bakos and it was shown to many visitors.

A new scheme has been introduced for Saturday night visitors whereby they are asked to make reservations regardless of the size of the group involved. In this way a more satisfactory distribution of the number of visitors is achieved.

Dr. Heard and his family are now living in Observatory House which was formerly occupied by the late Dr. Chant.

Dr. Helen Hogg spent two weeks in April relieving a teacher shortage in the Department of Astronomy at Mount Holyoke College in Massachusetts. Dr. MacRae was the guest speaker at the annual meeting of the Cleveland Astronomical Society in May. Dr. Oke attended the meeting in May of the American Astronomical Society at Harvard University.

Student assistants at the Observatory this year include: Miss K. Milles

and Messrs. Gustav Bakos, Pierre Demarque, Helge Mairo, James Hogg, David Oke, Wallace Russell, and Ralph Preston.

The Board of Governors have announced the promotion of Dr. Helen S. Hogg to Professor and of Dr. Leonard T. Searle to Assistant Professor.

J. F. H.

REVIEW OF PUBLICATIONS

New Horizons in Astronomy, edited by Fred L. Whipple. Pages x plus 181, 7⅛ × 10¼ inches. Washington, the Smithsonian Institute, 1956. For sale by the Superintendent of Documents, Washington 25, D.C. Price $1.50.

This work grew out of a committee appointed by the National Science Foundation to consider the needs of astronomy. Dr. Whipple, the chairman of the committee, asked a number of leaders in various fields of astronomy to write articles presenting their concepts of research projects most likely to advance the science of astronomy during the next decade. Besides helping the National Science Foundation in the allocation of their funds, the collection of articles would, it was believed, help younger astronomers to choose fertile fields of research, lead established astronomers to reflect on the planning of their activities and encourage research in new and neglected fields.

There are 39 articles divided into four groups entitled Techniques and Instrumentation, Related Sciences, Solar System, Stars and Galaxy. Some of the titles of the articles are: Radial Velocity, Photoelectric Astronomy, Computing Machines in Astronomy, Celestial Mechanics, Solar Physics, Stellar Atmospheres, 21-centimeter Research, Stellar Structure and Evolution. Each article is limited to a few pages, and, while the treatment varies from article to article, they are for the most part, easily read and they are all very informative regarding the present status of knowledge and the most urgent needs for new research. The book should be read by every student contemplating an astronomical career, and it will be profitable and interesting reading to anyone at all who is interested in the recent advances and the still greater looked-for advances of modern astronomy.

J. F. H.

Le Ciel et la Terre (Volume III of the Encyclopédie Française). Pages 452, 32 plates; 10 × 12 inches (hard-covered binder). Paris, Société Nouvelle de L'Encyclopédie Française, 1956. Price, depending on binding, 7450 Fr, 8850 Fr, 11950 Fr.

More than a third of this volume is devoted to astronomy; the remainder has to do with the earth. The book is entirely in French. The purpose is to give a survey of all the main problems connected with astronomy and the earth. To keep the book as small as possible, each subject has been discussed primarily with a view to presenting the current picture as experts in the various fields see it. As a consequence, the amount of older material is kept to a minimum, although the fundamental ideas are carefully retained. The final result is a book which is completely up-to-date.

In the section on astronomy there are 28 articles by such noted astronomers as Schatzman, Barbier, Kourganoff, and Couderc. Fields which have developed rapidly in recent years such as stellar evolution, the Hertzsprung-Russell diagrams for clusters, radio astronomy, and stellar associations are fully treated. Fields that have not changed radically in the last few years, however, have not been neglected.

The part of the book devoted to the earth is similar in structure to that on astronomy. Meteorology, the ionosphere, seismology, the crust of the earth, the age of the earth, climate, and the earth's interior, are only a sample of the many topics discussed.

Although a brief bibliography to material in book form is given, it is disconcerting to find very few references to the original research papers on which the text is based. This shortcoming, however, would possibly be difficult to overcome in a book of this kind.

Professional astronomers and geophysicists will find both parts of the book most interesting and informative. Scientists in other even unrelated fields, who are casually interested in astronomy or geophysics, will find the book readable and instructive. Students in particular will find it a valuable source of information. The fine diagrams and numerous beautiful photographs which are included, add materially to one's enjoyment of the book.

J. B. O.

VARIABLE STAR NOTES

American Association of Variable Star Observers

By MARGARET W. MAYALL, *Director*

Miscellaneous notes from A.A.V.S.O. light curves on the activities of some of the more interesting variable stars, during 1956 and early 1957. (Numbers appearing in brackets are apparent visual magnitudes.)

000339 *V Scl.* A bright maximum in the middle of June, about 9.3 magnitude, is the third consecutive maximum brighter than 10. The preceding three were fainter than 10th magnitude.

001838 *R And.* The interval between the 1955 and 1956 maxima was 374 days instead of the mean value of 410 days. The rising branch of the 1956 curve followed the slope of the mean curve, but was between 20 and 30 days too early. The maximum magnitude was 6.0, a magnitude brighter than normal, and was observed in the middle of October.

004047 *U Cas.* A faint maximum (9.2) early in November, followed 2 normal 8½ magnitude ones.

004746a *RV Cas.* The faint maximum (10.3) in the middle of July, was about 1 magnitude fainter than normal.

011272 *S Cas.* The current maximum, early February 1957, is somewhat fainter than 11, more than 2 magnitudes fainter than normal, and occurred about 670 days after the previous maximum. The published period is 611 days.

013238 *RU And.* The range of brightness from maximum to minimum continues to increase, and is now a little over 3 magnitudes.

021403 *o Cet.* A rather faint maximum (4.0) was observed on November 27, near the predicted date.

024217 *T Ari.* In recent years this variable has had a range of 3 magnitudes or more. About 20 years ago, the range was less than 1½ magnitudes.

025751 *T Hor.* A bright 8th magnitude maximum, observed in early January 1957, nearly a month later than predicted time, followed one a magnitude fainter, in the middle of May.

030514 *U Ari.* A 9th magnitude maximum was observed in the latter part of November. The previous one, about a magnitude brighter, was observed near the middle of November 1955.

034625 *U Eri.* A faint maximum (10.2) was observed the first of September.

042215 *W Tau.* The star is varying with about half a magnitude range. It is listed in the catalogue as having a 2½ magnitude range.

043065 *T Cam.* A normal wide maximum was observed in the middle of July following the narrow minimum and maximum in 1955.

044349 *R Pic.* Continues to be very irregular, but shows a tendency to alternating bright and faint minima.

050611 *Zinner 357.* The range of this star has decreased to less than half a

magnitude. See this JOURNAL, vol. 50, page 137, for the light curve from 1948 to 1955.

050848 *S Pic.* The maximum observed the first of November is 1½ magnitudes brighter than the maximum in 1955.

050953 *R Aur.* A normal maximum was observed in January 1957, about 10 days earlier than predicted.

054319 *SU Tau.* This R CrB-type variable remained nearly constant at maximum from July 1956 through the middle of April 1957.

054629 *R Col.* Two bright (8½) maxima, in December 1955 and October 1956, follow the very faint one (10½) in February 1955.

063462 *RR Pic.* This 1925 nova is decreasing very gradually. It was 11.4 magnitude throughout 1956.

065208 *X Mon.* The range has decreased to less than 1 magnitude.

074922 *U Gem.* A wide, bright (8.8) maximum, number 364, was observed on March 14, 1957, 136 days after the previous narrow maximum.

082476 *R Cha.* A bright (8) maximum observed in the middle of June, followed a 9½ magnitude one in 1955.

111561 *RY Car.* A faint maximum (12½) was observed in the middle of October. More observations are needed.

121418 *R Crv.* A bright maximum (7) in the latter part of October follows a faint one, nearly 9th magnitude, the first of January.

132422 *R Hya.* A marked still-stand at about 6th magnitude was observed on the increasing branch of the light curve, during August. Maximum occurred the first of November.

132706 *S Vir.* A bright maximum (6½) in the middle of July followed one a magnitude fainter in July 1955.

143417 *V Lib.* A very faint maximum (11) was observed the first of July.

150018 *RT Lib.* A bright maximum (8½) observed in the middle of July.

151731 *S CrB.* An 8th magnitude maximum followed one a magnitude brighter in 1955. The maxima have been repeating the pattern: faint, bright, bright, since 1950.

154428 *R CrB.* Nearly constant at 6th magnitude, from the time of its recovery from the shallow minimum in May 1956, through April 1957.

160210 *U Ser.* A faint maximum (9½) observed in the middle of July.

161138 *W CrB.* A 9th magnitude maximum was observed near the middle of April, between two 8th magnitude maxima in August 1955 and the middle of November 1956.

162119 *U Her.* A faint maximum (8.8) followed the very bright 7th magnitude one in 1955.

172486 *S Oct.* A very faint maximum (9.3) observed in early December.

174162 *W Pav.* Three faint maxima (10) observed in late July 1955, early May 1956, and the last of January 1957, follow an 8th magnitude one in October 1954.

175111 *RT Oph.* A bright maximum (8.2) in the middle of October, followed a faint one (10.2) the first of September 1955.

180514 *UZ Ser.* A faint U Gem-type variable observed by Thomas Cragg. He observed a maximum on May 18, and found it decreasing from another maximum on June 11 to 13.

184205 *R Sct.* Two very faint minima (8½) were observed during 1956, the first in early February, the other in the latter part of June.

185512 *ST Sgr.* An 8th magnitude maximum in the middle of September followed a 9½ magnitude one at the end of August 1955.

185851 *BL Tel.* This star is catalogued as an eclipsing variable with a period of 778 days. R. P. de Kock observed a minimum at 10.4 in October 1951, and one at 8.9 in November 1953. It has been constant at 7.9 since the middle of 1954.

191007 *W Aql.* A bright maximum (7.3) observed in the early part of July.

191033 *RY Sgr.* This CrB-type variable was found to be more than 2 magnitudes (8.8) below maximum at the beginning of the observing season near the last of January 1956. It dropped to 11.2 the first of March, then started an irregular recovery. It seemed fairly constant near 6.5 magnitude by the end of November.

192928 *TY Cyg.* A 9½ magnitude maximum in the last of July followed one a magnitude fainter in August 1955.

193509 *RV Aql.* A 9th magnitude maximum in early June followed a 10th magnitude one the first of November 1955.

193972 *T Pav.* The maximum nearly 7th magnitude in the last of October is the brightest one for about 25 years.

194632 *χ Cyg.* A 5.0 magnitude maximum was observed May 24, 1956.

195656 *RR Tel.* This interesting nova-like variable seems to have a slow variation from about 8.9 to 9.3 with a tendency to a period of 350 to 400 days.

201520 *V Sge.* Continues to have very rapid changes of one magnitude or more in a few hours (or minutes). It is a variable that should have a good series of photoelectric observations. In addition to the rapid changes, it frequently shows a periodicity of about 20 days, and a long-range variation of several years.

210124 *V Cap.* Two 10th magnitude maxima in the last of December 1955 and the last of September 1956 followed a bright maximum (8.2) in the middle of March 1955.

212030 *S Mic.* A bright maximum (8.4) the last of June, followed a faint 10th magnitude one in the middle of December 1955.

213753 *RU Cyg.* This double-period variable was nearly constant at about 8.5 magnitude from the predicted time of maximum in April 1956 through April 1957.

220714 *RS Peg.* A very faint maximum, fainter than 11th magnitude was observed the last of July.

222129 *RV Peg.* A faint 11th magnitude maximum in the middle of October followed a 9½ magnitude one in the middle of September 1955.

225120 *S Aqr.* A faint 9th magnitude maximum in the early part of May was followed by an 8th magnitude one in February 1957.

225859 *UV Cas.* This R CrB-type variable had a long shallow (about 1 mag.) minimum from October 1954 to October 1956. Maximum light is about 11.1 magnitude.

231539 *RY And.* A maximum of 10.8 magnitude observed in early September followed a 12th magnitude one the first of August 1955.

235150 *R Phe.* An 8th magnitude maximum in the latter part of August followed a faint maximum (9) in the middle of December 1955.

235265 *R Tuc.* A bright maximum (10) observed in early October followed a faint one (11) in the middle of December 1955.

Observations received during March and April, 1957: In March 50 observers contributed 3,142 observations, and in April 53 sent 4,535, a total of 7,677 for the two months.

Observer	March		April		Observer	March		April	
	Var.	Ests.	Var.	Ests.		Var.	Ests.	Var.	Ests.
Abbey, L. B.	8	8	..	..	Loehde, F.	5	5	..	..
Adams, R. M.	66	135	58	139	Lowder, W. M.	2	2	..	..
Anderson, C. E.	63	127	57	102	Maran, S. P.	30	34	..	..
Beidler, H. B.	21	31	30	80	Mayall, M. W.	..	..	6	6
Berg, R.	..	..	20	20	Melville, E. C.	..	..	9	21
Bieda, S. W.	..	..	4	18	Montague, A. C.	33	35	25	36
Breckinridge, J.	8	9	10	14	Morgan, F. P.	20	35	19	55
Brinley, F. J.	3	5	..	..	Oravec, E. G.	202	423	263	813
Buckstaff, R. N.	5	5	..	..	Parker, P. O.	78	106	64	101
Carlisle, J. H.	4	5	3	7	Pearcy, R. E.	5	5	4	4
Cragg, T. A.	111	114	193	208	Pearlmutter, A. E.	..	..	51	160
Cunningham, R.	..	..	2	2	Peltier, L. C.	25	99	15	66
Darsenius, G. O.	15	73	15	78	Pilcher, F.	8	8	5	5
Diedrich, DeL.	1	1	1	2	Price, F.	20	35	..	..
Diedrich, G.	4	5	7	12	Renner, C. J.	46	46	..	..
Erpenstein, O. M.	9	10	11	12	Rizzo, P. V.	13	14	23	43
Fernald, C. F.	166	344	180	681	Robinson, L. J.	7	12	50	103
Ford, C. B.	139	142	193	223	Roderick, T.	2	2	..	..
Fowler, C. E.	..	..	4	12	Rosebrugh, D. W.	15	112	12	108
Gemberling, R. H.	4	10	14	19	Royer, R.	3	3	5	5
Goldenblatt, P. P.	21	21	56	72	Segers, C. L.	15	26	19	60
Goodsell, J. G.	5	5	..	..	Sharpless, A. P.	9	11	9	10
Hartmann, F.	99	103	105	128	Skaritka, P.	36	50	..	..
Hein, G. J.	..	..	7	7	Sloan, M. A.	..	..	1	1
Hiett, L.	6	11	..	..	Solomon, L.	11	15	10	11
Houston, W. S.	..	..	5	16	Taboada, D.	98	162	186	424
Howarth, M.	..	..	15	15	Taulman, D. C.	..	..	15	15
Isenberg, H. D.	..	..	1	3	Thomas, M. A.	5	5	3	3
Jacobson, R.	2	2	2	2	Turtle, J. P.	3	4	..	..
Kelly, F. J.	10	10	11	13	Venter, S. C.	60	195	32	46
de Kock, R. P.	104	450	117	418	Walko, K.	..	..	3	3
Kofoed, R.	5	5	4	6	Wayland, K. A.	..	..	1	2
Lacchini, G. B.	15	67	28	105	Wolfe, J. C.	..	..	7	20

A.A.V.S.O. Nova Search Report, from George Diedrich, Chairman. The following 9 observers checked their nova search areas for a total of 129 area-nights as shown by the numbers after their names. The first number is the February and the second the March 1957 totals:

James Breckinridge: 12, 4; Delorne Diedrich: 10, 7; George Diedrich: 8, 13; Robert Jacobson: 9, 20; Andrew Keefer, Jr.: 0, 6; Earl Milton: 10, 0; Louis Rick: 6, 9; Samuel Terry: 4, 2; Jim Wesling: 9, 0.

METEOR NEWS

By Peter M. Millman, *National Research Council, Ottawa*

The I.G.Y. Programme of Meteor Observation

In the Journal for September-October of last year (vol. 50, p. 217, 1956) I outlined some programmes for meteor observation, which have been planned at the Dominion Observatory and the National Research Council in Ottawa. These will be carried out during the International Geophysical Year which commenced officially on July 1, 1957. A further note on this subject was published in the May issue of *Sky and Telescope* (vol. 16, p. 317, 1957).

It was pointed out in these articles that the visual I.G.Y. meteor programme offered a very fine opportunity for the amateur to make a personal contribution to the largest scientific effort yet attempted by man, a co-operative investigation in which over 55 nations are participating. I am pleased to say that the response to this request for volunteers has been very good and we have mailed a large number of record forms and instructions to groups and individuals from coast to coast of both Canada and the United States. At the date of writing only preliminary trial observations have been received but if one can judge by the general enthusiasm expressed in the letters received from prospective observers, we should collect some very valuable statistics on meteors during the next year and a half.

The study of meteors is a subject in the field of pure rather than applied science. However, with the advent of space flight, it is of some practical importance to have an accurate knowledge of the contents of space near the earth. The visual observer can still record meteors to a considerably fainter limit than the best camera yet designed, hence the value of this type of work.

Full instructions for the visual meteor programme, as well as pads of report forms, are now available to anyone interested. You may secure these, free of charge, by writing

Meteor Centre, I.G.Y.,
National Research Council, Ottawa, Ont.

A supply of this material has also been sent to the Secretary of each Centre of the R.A.S.C. for distribution to the local members. A number

of Centres have indicated their intention of forming teams of visual meteor observers. In addition to this, various astronomical societies in the United States have offered their assistance.

It is hoped to have some meteor counts for every night of the I.G.Y. However, a special effort is being made on selected nights, the International World Days. Where an active meteor shower occurs near the dark of the moon we have added a few extra observing nights for the meteor programme to round out the coverage of the important showers.

In Table I will be found a complete list of the I.G.Y. nights for special meteor observing. The nights added to the World Days have been indicated with an asterisk and should be inserted in the Observation Periods listed in the I.G.Y. Meteor Instructions which we are sending out.

Radar recording of meteors will be carried out continuously during the I.G.Y. at Ottawa and at several other points in Canada. On all nights listed in Table I additional high-powered radar equipment will operate at Ottawa. One of the important features of the combined visual-radar meteor programmes will be a comparison of the numbers of meteors recorded by the two methods. Such data, if collected on a uniform system for eighteen months, will give us a unique record of meteor statistics of a type that has not been available in the past.

TABLE I

I.G.Y. Nights for Special Meteor Observations

		1957	
June	26/27	Wed./Thu.	
	27/28	Thu./Fri.	
	28/29	Fri./Sat.	
July	3/4	Wed./Thu.	
July	25/26	Thu./Fri.	Delta Aquarid
	26/27	Fri./Sat.	
	27/28*	Sat./Sun.	
	28/29*	Sun./Mon.	
Aug.	11/12	Sun./Mon.	Perseid
Aug.	24/25	Sat./Sun.	
	25/26	Sun./Mon.	
Aug.-Sep.	31/1	Sat./Sun.	
Sept.	22/23	Sun./Mon.	
	23/24	Mon./Tue.	
Sept.	29/30	Sun./Mon.	
Oct.	21/22	Mon./Tue.	Orionid
	22/23	Tue./Wed.	
	23/24	Wed./Thu.	
Nov.	13/14	Wed./Thu.	Leonid
Nov.	20/21	Wed./Thu.	
	21/22	Thu./Fri.	
Dec.	12/13	Thu./Fri.	Geminid
	13/14*	Fri./Sat.	
	14/15*	Sat./Sun.	
	15/16	Sun./Mon.	
Dec.	20/21	Fri./Sat.	Ursid
	21/22	Sat./Sun.	

		1958	
Jan.	2/3	Thu./Fri.	Quadrantid
	3/4	Fri./Sat.	
Jan.	18/19	Sat./Sun.	
	19/20	Sun./Mon.	
Feb.	9/10	Sun./Mon.	Aurigid
Feb.	17/18	Mon./Tue.	
	18/19	Tue./Wed.	
Feb.	25/26	Tue./Wed.	
Mar.	19/20	Wed./Thu.	
	20/21	Thu./Fri.	
Mar.	27/28	Thu./Fri.	
Apr.	17/18	Thu./Fri.	Lyrid
	18/19	Fri./Sat.	
	19/20	Sat./Sun.	
	20/21*	Sun./Mon.	
	21/22*	Mon./Tue.	
May	4/5	Sun./Mon.	Eta Aquarid
May	17/18	Sat./Sun.	
	18/19	Sun./Mon.	
June	8/9	Sun./Mon.	
June	16/17	Mon./Tue.	
	17/18	Tue./Wed.	
June	23/24	Mon./Tue.	
July	15/16	Tue./Wed.	
	16/17	Wed./Thu.	
July	26/27	Sat./Sun.	Delta Aquarid

*Indicates nights added to list of I.W.D.

		1958	
Aug.	6/7	Wed./Thu.	
Aug.	10/11*	Sun./Mon.	Perseid
	11/12	Mon./Tue.	
	12/13*	Tue./Wed.	
	13/14	Wed./Thu.	
	14/15	Thu./Fri.	
Sept.	5/6	Fri./Sat.	
Sept.	12/13	Fri./Sat.	
	13/14	Sat./Sun.	
Sept.	19/20	Fri./Sat.	
Oct.	9/10	Thu./Fri.	
	10/11	Fri./Sat.	
	11/12	Sat./Sun.	
	12/13	Sun./Mon.	
Nov.	3/4	Mon./Tue.	
Nov.	9/10	Sun./Mon.	
	10/11	Mon./Tue.	
Nov.	17/18	Mon./Tue.	Leonid
Dec.	9/10	Tue./Wed.	Geminid
	10/11	Wed./Thu.	
	11/12*	Thu./Fri.	
	12/13	Fri./Sat.	
	13/14*	Sat./Sun.	
Dec.	16/17	Tue./Wed.	
		1959	
Jan.	2/3	Fri./Sat.	Quadrantid
	3/4	Sat./Sun.	
Jan.	8/9	Thu./Fri.	
	9/10	Fri./Sat.	

NOTES AND QUERIES

Mars in 1956

During the last close approach of Mars, Gerard P. Kuiper observed the planet with the 82-inch telescope of the McDonald Observatory from August 17 to September 17, 1956. The visual part of his programme is reported in the March 1957 issue of the *Astrophysical Journal*. The telescope was used with an eccentric diaphragm of 28-inch aperture placed over the 82-inch mirror. Most observations were made with a specially-constructed binocular attachment magnifying 900 diameters, which gave the planet an apparent diameter of about six degrees. It was found that the binocular arrangement decreased eyestrain. Some observations were made with filters over a single eyepiece with a magnification of 650 times. Estimates of colours were made with the aid of a colour chart of 180 rectangular patches of colour, placed at arm's length from the eyepiece, and illuminated by a light with the quality of daylight.

It had been hoped to observe the surface details of the planet with the best resolution obtainable. However, an exceptional display of dust storms masked the surface details and was one of the striking features of this opposition. Between the nights of August 29 and 30 an enormous dust storm developed over the central part of Mare Sirenum and adjacent regions. By the next night the dust storm had stretched into a ribbon-like shape, covering a wide range in longitude in a remarkably short time. By September 1 it had spread south-eastward from Mare Sirenum and for the next couple of days the planet had a ghostlike appearance, with dust covering all but the south polar region. The region of Mare Sirenum began to clear by September 4, although the traces of the dust storm did not disappear completely for another ten days.

Another unusual feature of this opposition was the re-formation of the south polar cap about a week after it had completely disappeared. Kuiper found the cap to be composed of clouds on September 9 and 10; by the 14th the appearance was such as to suggest that the cap was an actual deposit on the surface. Observations during October and November 1956 showed that the inner part of the polar cap remained during this time.

Because of the dust storms, less was seen on the surface of the planet than during the most distant oppositions. Kuiper suggests that the excessive dust storms indicate that the season on Mars was unusual, possibly unusually dry.

R. J. N.

A New Intergalactic Cluster

A new globular cluster has been identified on the Palomar Sky Survey charts by Ambarzumian and reported by R. K. Shakhbazian in the *Russian Astronomical Circular*, no. 177, p. 11, 1957. The 1950 coordinates of the new cluster are $\alpha = 10^h52^m03^s$, $\delta = +40°44'$. From the blue and red prints it was possible to determine the magnitudes and the colour indices of 16 stars relative to M3 as a standard. Out of 16 stars 15 proved to be red giants, the colour index of the other star was 0.4. The colour-magnitude diagram is typically that of globular clusters.

Making use of Shapley's assumption that the absolute photographic magnitude of the sixth star in the cluster is —0.9 and making allowance for interstellar absorption the author has derived the distance modulus $m - M = 20.6$ corresponding to a distance of 130 kpc. Evidently this globular cluster is situated far beyond the limits of our galaxy. Diameter of the cluster is 1.3 minutes of arc or 52 pc. The visual magnitude of the brightest star is 17.4 and the apparent magnitude of the whole cluster is about 15.0, corresponding to an absolute magnitude of $M_v = -5.6$.

This cluster shows striking similarities with the globular cluster no. 4 of Abell's list, found by Hubble and A. G. Wilson (*P.A.S.P.*, vol. 67, p. 27, 1955), and studied by Sidney van den Bergh (*P.A.S.P.*, vol. 68, p. 449, 1956). The distance modulus of the latter is 20.8 corresponding to a distance of 145 kpc. Both clusters are therefore "intergalactic tramps".

G. A. B.

Temperatures at the South Pole

The results of the first measures of the temperature at the Amundsen-Scott South Pole Station have recently been announced in *Science* (May 10, 1957). This station, at an altitude of 10,000 feet, was established to take readings during the International Geophysical Year. The temperatures on March 27, 1957 were reported as being —71° F. at the surface, —31° F. at 3,300 feet, and —62° F. at 11,500 feet above the surface. The values are broadcast from a radiosonde attached to a balloon released into the air, and are recorded by a receiver on the ground. Temperatures are expected to drop further as midwinter at the South Pole approaches; temperatures of —120° F. may occur. The lowest reading so far observed at the South Pole is —89° F. on April 2, 1957. The lowest temperature ever recorded in North America is —81° F., observed at Snag, Yukon Territories, in February 1947. The lowest world record is —90° F., observed in north-eastern Siberia in February 1933.

For the first time, twice-daily weather maps of the Antarctic are being prepared, using the meteorological data from all the I.G.Y. Antarctic stations. From a study of the temperatures and circulation of the air in the Antarctic, it is expected that its effects on world weather and world climate may be established.

R. J. N.

MEETINGS OF THE SOCIETY

AT TORONTO

January 24, 1956—The meeting was held in the McLennan Physics Laboratory, University of Toronto, Dr. H. L. Welsh presiding.

Dr. D. A. MacRae described Radio Telescopes, their operations and scope; he then reported on his trip to the Conference on Radio Astronomy held at Manchester, England and particularly of the 250-foot radio telescope being constructed at Jodrell Bank. The conference was divided into five symposia: Hydrogen line emission; Point Sources; Galactic and Extra-Galactic Structures; The Sun; Meteors and Planets. Dr. MacRae reports that plans exist for building nine new antennae in the U.S.A. which include 140-foot and 600-foot receivers.

Dr. William Wehlau of the University of Western Ontario spoke of the history, purpose and future plans of The Hume Cronyn Observatory. In addition to collaborating with other observatories, work will be done in the fields of eclipsing binaries and long period variables.

February 7, 1956—Meeting was held in the McLennan Physics Laboratory, University of Toronto, Dr. H. L. Welsh presiding.

Dr. Rupert Wildt, Associate Professor of Astrophysics, Yale University was guest speaker, his subject, "Inside The Planets". A summary was given of what had been learned about our own planet, earth, and what theory indicated as the probable structure of the interior.

At the present time more can be learned about the interior of the other planets. It is assumed that bodies in the solar system have had sufficient time to cool down from any initial high temperature which may have existed, and we are therefore dealing with solid, not gaseous bodies. The Jovian planets have a mean density much lower than those of the terrestrial type. Low densities of Jupiter and Saturn allow us to construct certain models assuming a composition of either hydrogen or helium. Earlier models did not take into consideration the compressibility of these gases. Theoretical considerations would indicate that these bodies are composed of hydrogen or helium and quite likely a mixture. A suggested mixture being 70% hydrogen and 30% helium with less than 1% heavier elements present. Recent photometric measures of the occultation of a Jovian moon indicates an atmosphere of low molecular weight; this supports the case for hydrogen.

Dr. J. A. Jacobs proposed a vote of thanks.

March 6, 1956—The meeting was held in the McLennan Physics Laboratory, University of Toronto. Dr. H. L. Welsh presiding. This was a joint meeting with the Toronto and District Science Teachers Association.

The programme was presented by the Telescope-Making Group and the Observation and Study Group. Various phases of telescope-making were covered by Mr. Morgan Salter, Mr. K. Stevenson and Mr. Jesse Ketchum. Demonstrations were given and a question and answer period conducted.

Dr. J. F. Heard presented a very interesting talk about sun-dials.

Mr. D. Gerrie gave a demonstration of the conservation of angular momentum with special reference to the earth-moon system. Mr. Ross Lemire demonstrated his four-inch reflecting telescope equipped with Selsyn setting circles. Mr. R. R. Broadfoot showed how a simple device could be made for projecting the solar image.

March 20, 1956—The Toronto Centre met at 8:00 p.m. in the McLennan Laboratory, University of Toronto; the President, Dr. H. L. Welsh, in the chair. Minutes of the meeting of March 6 were adopted.

Dr. J. L. Locke, head of the stellar physics division of the Dominion Observatory, Ottawa, spoke on "Harnessing the Energy of the Sun". He presented a general summary of problems connected with the utilization of solar energy, which he called "our greatest natural resource". Present deposits of fossil fuels—coal and petroleum—are solar energy which reached the earth as radiation and have been stored for millions of years. Hydro-electric power also is dependent on the water-raising power of the sun. Today the aim of workers in the field of solar radiation is to learn how to make immediate use of this energy. The fossil fuels will be unable to meet demands for more than a few centuries, and the "pinch" will be felt long before supplies actually reach a diminishing point.

Some experts in the field, Dr. Locke said, are "rash enough" to predict a day when use of direct solar energy will equal that derived from the fossil fuels, and he foresaw considerable use of solar radiation for heating buildings. One such installation, near Boston, stores enough energy during periods of sunshine to continue to heat the building for ten consecutive cloudy days. It was unlikely this type of device will be of much use in the Canadian climate, however, as the "collector" would have to be much larger than the roof area of an ordinary house.

Dr. Locke pointed out that the amount of solar energy falling on one square yard in one day is equal to one horsepower; that falling on one square mile is equivalent to the energy of a Hiroshima-type atomic bomb, and that falling on a square 200 miles to a side, would equal the entire world's supply of energy derived from present fuels. Cookers using parabolic mirrors to focus the sun's heat already are in use in arid countries, such as parts of India, and Russia is using a large solar converter to supply power to a cannery. Another recent use of solar energy is in the solar battery developed by the Bell Telephone Laboratories and which converts 11 per cent. of the radiation falling on it into electrical energy. Although still very expensive, such batteries are now being used to power a rural telephone line in the state of Georgia.

A further use of solar radiation is in the solar furnace which, employing large mirrors to focus heat at a point, is able to produce temperatures of more than 3000° C., somewhat higher than in the best electric furnace, for research studies of metals and silicates at very high temperatures.

Dr. J. B. Oke thanked the speaker on behalf of the Toronto Centre, and the meeting was adjourned.

April 3, 1956—The meeting was held in the McLennan Physics Laboratory, University of Toronto. Mr. G. Cooper presiding.

Dr. D. MacRae introduced the speaker Dr. J. P. Wild of The Commonwealth Science and Industrial Research Organization, Australia. Dr. Wild's subject was, "Radio Astronomy Down Under". The speaker dealt with the history, results and current problems of the newest field of astronomical endeavour, radio astronomy.

Dr. Wild spoke specifically of solar flares when radio emission increases markedly. One and a half days after outburst high energy particles reach the earth with speeds of 500 to 1,000 km./sec., others travel at one-tenth the velocity of light.

Bright radio sources cannot always be identified with known optical objects. Objects have been detected with the larger telescopes working in conjunction with radio telescopes. About 2,000 radio stars are known of which only 20 or 30 can be identified; many are exceedingly distant. Many of these objects may be ten times further away than optical instruments can now detect.

Mr. Ross Lemire thanked the speaker.

April 17, 1956—The meeting was held in the McLennan Physics Laboratory, University of Toronto, Dr. H. L. Welsh presiding.

Speaker for the evening was Dr. Dean B. McLaughlin, Professor of Astronomy, University of Michigan. Dr. McLaughlin's subject was "The Surface Of Mars", see this JOURNAL, vol. 50, p. 193.

Mr. R. R. Broadfoot thanked the speaker.

October 16, 1956—The meeting was held at the David Dunlap Observatory, Mr. G. A. Cooper presiding. This meeting was the annual open house for R.A.S.C. members at the observatory. The sky being clear Mars was observed by members through the 74-inch and 19-inch reflectors; the moon also was viewed through the 6-inch refractor.

Dr. MacRae demonstrated a model of the new radio telescope now under construction at the observatory. He explained its operation and plans for its use.

Dr. Helen Hogg explained the peculiarities of the variable star Algol which was on this very occasion at "minimum". Slides were used to explain this phenomenon.

Mr. R. R. Broadfoot gave a star talk on the observatory lawn. Members had an opportunity to actually observe Algol.

Mr. J. Ketchum supervised a display of telescopes made by amateurs. Members had further opportunity to view the moon and Mars through these instruments.

October 30, 1956—The meeting was held in the McLennan Physics Laboratory, University of Toronto, Mr. G. A. Cooper presiding.

Mr. J. H. Horning introduced the speaker, Dr. C. S. Beals, Dominion Astronomer. "A Search For Canadian Meteorite Craters", was the subject for the evening. Dr. Beals reviewed the problem of the origin of the craters on the moon. Since the discovery by Barringer (1906) of the great meteorite crater of Arizona, increased efforts have been made to discover topographic features on the earth which may have been caused by meteoric impact. A curve in which logarithm of the depth is plotted against logarithm of diameter will include bomb craters, meteorite craters and lunar craters. The newly discovered Quebec Crater and North African Crater (1953) overlap the lunar craters in the upper portion of the curve.

An extensive search was made of Canadian Air Photo aerial photographs of the Canadian Shield for anything of a circular nature. If such were found they were examined critically with stereoscopic aid to see whether they bore any resemblance to a crater.

Effort is being made to make on-the-site analyses of these promising features to see whether geophysical or geological techniques can determine whether the suspected feature is actually meteoric. The possibility of placing supposed craters on an age scale exist. The nature of surrounding country and of sediments within the crater can be used to date the approximate birth of the craters. See this JOURNAL, vol. 50, p. 203, 1956.

Dr. V. B. Meen thanked the speaker.

November 13, 1956—The meeting was held in the McLennan Physics Laboratory, University of Toronto, Mr. G. A. Cooper presiding.

Dr. J. F. Heard spoke of the passing of Mr. T. H. Mason a former Treasurer of the R.A.S.C. Toronto Centre.

Dr. J. F. Heard spoke of a proposal to increase the annual fee for membership to five dollars, this being effective in 1958.

Mr. G. A. Cooper introduced the speaker, Dr. Helen S. Hogg. This was an illustrated lecture entitled "My Year With The National Science Foundation". The speaker explained the nature of the National Science Foundation and what it was trying to accomplish. When N.S.F. was first established, in Washington, to foster basic scientific research in the U.S.A. its budget was about three million dollars; it has since increased to forty-one million dollars for the current year.

Dr. H. Hogg acted as Program Director for Astronomy. Proposals for grants to aid researchers, finance research programs, make new instruments available, modernize older equipment, assisting in the salaries of teachers and investigators, supporting conferences held to discuss active fields of astronomical research, were considered and financed as deemed wise by the advisory panel. Plans to locate and build a National Astronomical Observatory and a National Radio Observatory are actually being brought to completion.

Dr. Hogg showed numerous coloured slides which very beautifully outlined her one year's duty with the Foundation.

Mr. C. F. Publow thanked the speaker.

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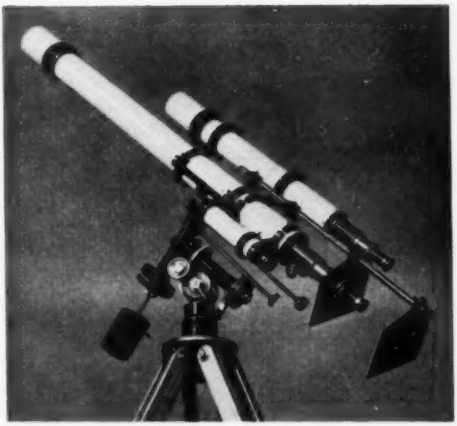

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